A Novel Detection Approach for Cardio-Respiratory Disorders Using PPG Signals

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ABSTRACT

The aim of the study was to determine the use of Photoplethysmography (PPG) as a tool for identifying cardiac and respiratory disorders using Decision tree mining technique. PPG signals were recorded from 45 healthy volunteers in the 19-22 age group. Recordings were carried out under normal, induced cardiac stress and induced apnea conditions to assess the changes in the PPG morphology under these settings. Three features, stiffness index (SI), reflection index (RI) and power ratio (PR), have been used for classification. Classification accuracy of 94.44% and 97.19% has been achieved for induced cardiac stress and induced apnea recordings respectively, using the decision tree classifier. The study indicates that PPG can be used as an effective screening tool for preliminary diagnosis of different cardiac and respiratory conditions. The results need to be validated for large datasets as well as for offline analysis of measurements from real life situations.

Keywords: Apnea, Cardiac, Decision Tree, Photoplethysmography, Power Ratio, Reflection Index, Stiffness Index

1. INTRODUCTION

Photoplethysmography (PPG) is a non-invasive measurement technique, suitable for measuring blood volume changes in the micro-vascular bed of tissue (Lin, Liu, Tsai, & Chen, 2009). PPG has been extensively used in different clinical settings such as monitoring of blood oxygen saturation, heart rate, cardiac output, blood pressure and respiration (Allen, 2007). The measurement is performed by projecting visible or infra-red light on the surface of the skin and detecting the transmitted or reflected light from the blood vessels. The fluctuations

DOI: 10.4018/ijbce.2012070102
in signal intensity may either be periodic or non-periodic, arising due to combined influence of perfusion pressure and sympathetic vascular control (Avolio, 2002). PPG signals can be acquired at various sites of the body such as fingers, earlobes, forehead or toes, allowing different possibilities for data acquisition protocols (Erts, Rubins, & Spigulis, 2009).

The PPG consists of two components – a slow, varying DC offset due to skin and electrode response, and an AC component, typically around 1 Hz, which reflects blood volume pulsations (Mohamed, Mahamod, & Zainol, 2004). The amplitude fluctuations in the PPG signal are influenced by respiration and the activity of sympathetic nervous system which, in turn, are attributed to autonomous control of peripheral vessels. The forward pressure wave is created due to ventricular contraction (Laurent et al., 2007; Millasseau, Kelly, Ritter, & Chowienczyk, 2002; Millasseau, Ritter, Takazawa, & Chowienczyk, 2006). It flows from the heart to the aorta and other smaller arteries, and is called the rising phase or systolic component. These waves are then reflected from the periphery at main branch points and they constitute the diastolic component. The point of reflection of the wave is characterized by the dicrotic notch, whose height is considered to be a measure of peripheral pressure wave reflection (Chowienczyk et al., 1999; Oliver & Web, 2003). Pulse propagation time (PPT) is the time interval between the systolic and diastolic peaks. Qualitatively, the systolic peak (anacrotic phase) corresponds to the heart condition and the diastolic peak (catacrotic phase) is used to determine elasticity and other features of the vascular system (Erts, Rubins, & Spigulis, 2009).

Figure 1 shows the morphology of a typical PPG waveform.

The PPG signal shape contains certain coded information regarding the cardiovascular and respiratory state of the subject and a detailed shape analysis eventually provides clinical data for early detection of cardiovascular and respiratory abnormalities. The potential for extracting diagnostic information from the PPG has been reviewed (Murray & Foster, 1996). Ageing and arterial diseases are said to have an effect on the variations of the AC component in PPG waveform. The peripheral pulse is used to assess the state of health and disease in subjects (Anne & Michael, 2005). A weak or delayed response indicates signs of occlusive arterial diseases (Allen & Murray, 2002). During apnea, vasoconstriction occurs and it is reflected in the PPG signal by a decrease in the fluctuation of amplitude. Several
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